

Section III: Selected M&V Methods—Option A

The chapters in this section describe technology-specific M&V methods associated with Option A, which is one of the four M&V options that can be used in implementing federal ESPC projects. The methods described here are for the most typical ECMs, such as lighting retrofits, and they represent of the range of methods available.

Chapter 6 introduces Option A. The measure-specific M&V methods based on Option A and presented here are as follows:

Chapter	ECM	Method Number
7	Lighting efficiency	LE-A-01, LE-A-02
8	Lighting controls	LC-A-01, LC-A-02
9	Constant-load motors efficiency	CLM-A-01
10	Variable-speed drive retrofit	VSD-A-01
11	Chiller replacements	CH-A-01, CH-A-02

6

Introduction to Option A

An Option A-based M&V method involves a retrofit or system-level M&V assessment. The approach is intended for retrofits where either performance factors (e.g., end-use capacity, demand, power) or operational factors (lighting operational hours, cooling ton-hours) can be spot or short-term measured during the baseline and post-installation periods. The factor not measured is stipulated based on assumptions, analysis of historical data, or manufacturer's data. Using a stipulated factor is appropriate only if supporting data demonstrates its value is not subject to fluctuation over the term of the contract.

All end-use technologies can be verified using Option A; however, the accuracy of this option is generally inversely proportional to the complexity of the measure. In addition, within Option A, various methods and levels of accuracy in verifying performance/operation are available. The level of accuracy depends on the validity of assumptions, quality of the equipment inventory, and whether spot/short-term measurements are made. The penalty associated with low accuracy is not achieving the estimated measure savings and the associated utility bill cost reductions.

Option A can be applied when identifying the potential to generate savings is the most critical M&V issue, including situations in which:

- The magnitude of savings is low for the entire project or a portion of the project to which Option A can be applied.
- The risk of achieving savings is low or ESCO payments are not directly tied to actual savings.

6.1. Approach

Option A is an approach designed for projects in which the potential to generate savings must be verified, but the actual savings can be determined from stipulated factors, short-term data collection, and engineering calculations. Post-installation energy use is not measured throughout the term of the contract. Post-installation and perhaps baseline energy use is predicted using an engineering or statistical analysis of information that does not involve long-term measurements.

With Option A, savings are determined by measuring the capacity, efficiency, or operation of a system before and after a retrofit and by multiplying the difference by a stipulated factor. Stipulation is the easiest and least expensive method of determining savings. It can also be the least accurate and is typically the method with the greatest uncertainty of savings. This level of verification may suffice for certain types of projects in which a single factor represents a significant portion of the savings uncertainty. Option A is appropriate for projects in which both parties agree to a payment stream that is not subject to fluctuation due to changes in the operation or performance of the equipment. Payments could be subject to change based on periodic measurements, however.

6.2. M&V Considerations

Option A includes procedures for verifying the following:

- Baseline conditions have been properly defined.
- The equipment and/or systems contracted to be installed were installed.
- The installed equipment/systems meet contract specifications in terms of quantity, quality, and rating.
- The installed equipment is operating and performing in accordance with contract specifications and is meeting all functional tests.
- The installed equipment/systems continue, during the term of the contract, to meet contract specifications in terms of quantity, quality, rating, operation, and functional performance.

This level of verification is all that is contractually required for certain types of performance contracts. Baseline and post-installation conditions (e.g., equipment quantities and ratings such as lamp wattages, chiller kW/ton, or motor kW) represent a significant portion of the uncertainty associated with many projects.

All end-use technologies can be verified using Option A; however, the accuracy of this option is generally inversely proportional to the complexity of the measure. Thus, the savings from a simple lighting retrofit will typically be more accurately estimated with Option A than the savings from a chiller retrofit. If greater accuracy is required, Options B, C, or D may be more appropriate.

Within Option A, various methods and levels of accuracy in verifying performance are available. The level of accuracy depends on the quality of assumptions made, and it can also depend on whether an inventory method is used for ensuring nameplate data and quantity of installed equipment or whether short-term measurements are used for verifying equipment ratings, capacity, operating hours and/or efficiency. The potential to generate savings may be verified through observation, inspections, and/or spot/short-term metering conducted immediately before and/or immediately after installation. Annual (or some other regular interval) inspections may also be conducted to verify an ECM's or system's continued potential to generate savings.

Savings potential can be quantified using any number of methods, depending on contract accuracy requirements. Equipment performance can be obtained either directly (through actual measurement) or indirectly (through the use of manufacturer data). There may be sizable differences between published information and actual operating data. Where discrepancies exist or are believed to exist, field-operating data should be obtained. This could include spot measurement for a constant load application. Short-term M&V can be used if the application is not proven to be a constant load. Baseline and post-installation equipment should be verified with the same level of detail. Either formally or informally, all equipment baselines should be verified for accuracy and for concurrence with stated operating conditions. Actual field audits are almost always required.

7

Lighting Efficiency: No Metering and Metering of Fixture Wattages Only

7.1 ECM Definition

Lighting ECM projects covered by this verification plan are as follows:

- Retrofits of existing fixtures, lamps, and/or ballasts with an identical number of more energy-efficient fixtures, lamps, and/or ballasts
- De-lamping with or without the use of reflectors

These lighting efficiency projects reduce demand; however, the fixtures are assumed to have the same pre- and post-retrofit operating hours.

7.2 Overview of Verification Methods

Two verification methods are covered in this chapter. For both methods, the hours of operation are stipulated. The methods differ in how the fixture wattages are determined.

Surveys are required of existing (baseline) and new (post-installation) fixtures. Corrections may be required for non-operating fixtures. Light level requirements may be specified for projects that involve reducing lighting levels.

Method LE-A-01 does not require metering of fixtures. Fixture wattages will be from a standard table unless other documentation, such as the manufacturer's data, is provided.

Method LE-A-02 requires spot or short-term wattage measurements of a representative sample of baseline and post-installation fixtures or fixture circuits to establish demand. This method is more time-consuming and expensive, but it may result in more accurate savings estimates if fixture wattage measurements are done carefully.

7.3 Calculation of Demand and Energy Savings

7.3.1 Baseline Demand

The baseline conditions identified in the pre-installation equipment survey may be defined by either the federal agency or the ESCO. If the baseline is defined by the federal agency, the ESCO will have an opportunity to verify the baseline. If the baseline is defined by the ESCO, the federal agency will verify the baseline.

In the pre-installation equipment survey, the equipment to be changed and the replacement equipment to be installed are inventoried. The location of the equipment (e.g., the rooms it is in) and building floor plans should be included with the survey submittal. The surveys will include, in a set format, fixture, lamp and ballast types, usage area designations, counts of operating and non-operating fixtures, and whether the room is air-conditioned and/or heated.

Method LE-A-01—No Metering

Fixture wattages will be from a standard table unless other documentation is provided. A standard table of fixture wattages should contain common lamp and ballast combinations. If a fixture is not found in the table, the party conducting the pre-installation equipment survey should either (a) conduct instantaneous wattage measurements for a representative sample of fixtures or (b) provide an approved, documented source of the fixture wattages for approval by the other party.

In general, a standard table of fixture wattages should be used for the baseline fixtures, and documented manufacturers' data should be used for post-installation fixtures.

Method LE-A-02—Fixture Wattage Metering

Fixture wattages will be measured. An example of a metering protocol is:

The ESCO will take 15-minute, true root-mean-square (RMS) wattage measurements from at least six fixtures representative of the baseline and post-installation fixtures (actual values may vary by application). Readings will be averaged to determine per-fixture wattage values. For post-installation fixtures, readings should be taken only after the new fixtures have been operating for at least 100 hours. Meters used for this task will be calibrated and have an accuracy of $\pm 2\%$ of reading or better.

7.3.2 Adjustments to Baseline Demand

Before the new lighting fixtures are installed, adjustments to the baseline demand may be required for non-operating fixtures. In addition, after ECM installation, adjustments to baseline demand may be required because of remodeling or changes in occupancy. Methods for making adjustments should be specified in the site-specific M&V plan.

The party responsible for defining the baseline will also identify any non-operating fixtures. Non-operating fixtures are those that are *typically operating* but that have broken lamps, ballasts, and/or switches that are *intended for repair*.

A de-lamped fixture is not a non-operating fixture, and de-lamped fixtures should have their own unique wattage designations. Fixtures that have been disabled or de-lamped, or that are broken and not intended for repair, should not be included in the calculation of baseline demand or energy. They should, however, be noted in the lighting survey to avoid confusion.

For non-operating fixtures, the baseline demand may be adjusted by using values from the standard table of fixture wattages or from fixture wattage measurements. *The adjustment for inoperative fixtures will be limited to some percentage of the total fixture count per facility; e.g., 10%.* If, for example, more than 10% of the total number of fixtures are inoperative, the number of fixtures beyond 10% will be assumed to have a baseline fixture wattage of zero.

7.3.3 Post-Installation Demand

The post-installation conditions identified in the post-installation equipment survey will be defined by the ESCO and verified by the federal agency.

Method LE-A-01—No Metering

Fixture wattages will be from a standard table unless other, approved documentation is provided. See part 7.3.1

Method LE-A-02—Fixture Wattage Metering

Fixture wattages will be measured. See part 7.3.1.

7.3.4 Operating Hours

Operating hours will stipulated and agreed to by the federal agency and the ESCO. Sources of stipulated hours can be any of the following:

- Results from other projects in similar facilities
- Studies of lighting operating hours
- Building occupancy hours multiplied by a lighting load factor
- Pre-metering of representative areas by the ESCO or federal agency.

Operating hours should be defined for each unique usage group within a building or facility that is being retrofit.

Usage groups are areas with similar operating hours (either annual operating hours, seasonal operating hours, or operating hours per the electric utility's time-of-use periods). Examples of usage groups are private offices, open offices, conference rooms, classrooms, and hallways.

Within each group, the range of operating hours should be narrow. Each usage group type should have similar use patterns and comparable average operating hours.

7.4 Equations for Calculating Energy and Demand Savings

7.4.1 Energy

To determine estimates of energy savings for lighting efficiency projects, use the following equation:

$$\begin{aligned} \text{kWh Savings}_t \\ = \sum_u [(kW/\text{Fixture}_{\text{baseline}} \times \text{Quantity}_{\text{baseline}} - kW/\text{Fixture}_{\text{post}} \times \text{Quantity}_{\text{post}}) \times \text{Hours of Operation}]_{t,u} \end{aligned}$$

where:

kWh Savings = kilowatt-hour savings realized during the post-installation time period t

$kW/\text{Fixture}_{\text{baseline}}$ = lighting baseline demand per fixture for usage group u

$kW/\text{Fixture}_{\text{post}}$ = lighting demand per fixture during post-installation period for usage group u

$\text{Quantity}_{\text{baseline}}$ = quantity of affected fixtures before the lighting retrofit for usage group u , adjusted for inoperative and nonoperative lighting fixtures

$\text{Quantity}_{\text{post}}$ = quantity of affected fixtures after the lighting retrofit for usage group u

Hours of Operation = number of operating hours during the time period t for the usage group u , assuming operating hours are the same before and after measure installation.

7.4.2 Demand

Demand savings can be calculated as either an average reduction in demand or as a maximum reduction in demand.

Average reduction in demand is generally easier to calculate. It is defined as kWh savings during the time period in question (e.g., utility summer peak period) divided by the hours in the time period.

Maximum demand reduction with respect to cost savings, is typically the reduction in utility meter maximum demand under the terms and conditions specified by the servicing utility. For peak load reduction, for example, the maximum demand reduction may be defined as the maximum kW reduction averaged over 30-minute intervals during the utility's summer peak period. The maximum demand reduction is usually calculated to determine savings in utility peak demand charges. Thus, if utility demand savings are to be determined, each site must define (a) how the reduction will affect the utility bill and (b) how the demand reduction will be calculated for purposes of payments to ESCOs.

7.4.3 Interactive Effects

Lighting efficiency projects may have the added advantage of saving more electricity by reducing loads associated with space-conditioning systems. The reduction in lighting load, however, may also increase space heating requirements. Three options exist for estimating savings (or losses) associated with the interactive effects of lighting efficiency projects:

1. Ignore interactive effects
2. Use agreed-to, “default” interactive values, such as a 5% addition to lighting kWh savings to account for additional air-conditioning savings
3. Calculate interactive effects on a site-specific basis

7.5 Pre- and Post-Installation Submittals

For each site, the ESCO submits a project pre-installation report that includes the following:

- A project description and schedule
- A pre-installation equipment survey
- Estimates of energy savings
- Documentation on utility billing data
- Projected budget
- Site-specific M&V plan and schedule.

If the federal agency defines the baseline condition, the ESCO must verify an agreed-to pre-installation equipment survey.

The ESCO submits a project post-installation report following project completion and defines projected energy savings for the first year. In addition, the report includes most of the same components as the project pre-installation report, as well as information on actual rather than expected measure or ECM installations.

7.6 Site-Specific Measurement and Verification Plan

The site-specific measurement and verification approach may be prespecified in the ESPC between the federal agency and the ESCO and/or agreed to after the award of the project. In either case, before the federal agency approves the project construction, the ESCO must submit a final M&V plan that addresses the following elements on a site-specific basis:

- Overview of approach
- Specification of savings calculations
- Identification of corresponding variables and specification of assumptions
- Identification of data sources and/or collection techniques
- Specification of data collection (i.e., sampling, site inspection, and monitoring plan), if required
- Identification and resolution of any other M&V issues.

Specific M&V issues related to lighting efficiency that need to be addressed include the following:

- Decision whether to establish baseline fixture wattages at current efficiency standards
- Designation of usage groups for defining stipulated lighting operating hours
- Assessment of non-operating fixtures
- Choice of methods to account for changes to baseline and post-installation fixture counts and types due to remodels
- Identification of interactive impact approach.

In addition, project re- and post-installation reports should identify specific steps required to implement the M&V plan.

8

Lighting Controls: No Metering and Metering of Fixture Wattages Only

8.1 ECM Definition

The lighting projects covered by this verification plan are as follows:

- Installation of occupancy sensors or daylighting controls without any changes to fixtures, lamps, or ballasts.
- Installation of occupancy sensors or daylighting controls with changes to fixtures, lamps, and/or ballasts.

These lighting controls projects reduce fixture operating hours.

8.2 Overview of Verification Methods

Two methods are covered in this chapter. For both methods, the baseline and post-installation fixture hours of operation are stipulated. The methods differ in the way that the fixture wattages are determined for lighting controls projects.

Surveys are required of existing (baseline) and new (post-installation) fixtures and lighting controls. Corrections may be required for non-operating fixtures. Light level requirements may be specified for projects that involve reducing lighting levels.

M&V Method LC-A-01 requires no metering of fixtures. Fixture wattages will be from a standard table unless other documentation, such as the manufacturer's data, is provided.

M&V Method LC-A-02 requires spot or short-term wattage measurements of a representative sample of baseline and post-installation fixtures or fixture circuits to establish demand. This method is more time consuming and expensive, but it may result in more accurate savings estimates if fixture wattage measurements are done carefully.

8.3 Calculation of Demand and Energy Savings

8.3.1 Baseline Demand

The baseline conditions identified in the pre-installation equipment survey may be defined by either the federal agency or the ESCO. If the baseline is defined by the federal agency, the ESCO will have the opportunity to verify the baseline. If the baseline is defined by the ESCO, the federal agency will verify the baseline.

In the pre-installation equipment survey, the existing lighting equipment and the controls (and lighting equipment to be changed, if an efficiency retrofit is to be done concurrently) are inventoried. Room location and corresponding building floor plans should be included with the survey submittal. The surveys will include, in a set format, fixture, lamp and ballast types; lighting control types; usage area designations; counts of operating and non-operating fixtures; and whether the room is air-conditioned and/or heated.

Method LC-A-01—No Metering

Fixture wattages will be from a standard table unless other documentation is provided. A standard table of fixture wattages should contain common lamp and ballast combinations. If a fixture is not found in the table, the party conducting the pre-installation equipment survey should either (a) conduct instantaneous wattage measurements for a representative sample of fixtures (i.e., Method LE-A-02) or (b) provide an approved, documented source of the fixture wattages for approval by the other party.

In general, a standard table of fixture wattages should be used for the baseline fixtures, and documented manufacturers' data should be used for post-installation fixtures.

Method LC-A-02—Fixture Wattage Metering

Fixture wattages will be measured. An example of a metering protocol is:

The ESCO will take 15-minute, true RMS wattage measurements from at least six fixtures representative of the baseline and post-installation fixtures (actual values may vary by application). Readings will be averaged to determine per-fixture wattage values. For post-installation fixtures, readings should be taken only after the new fixtures have been operating for at least 100 hours. Meters used for this task will be calibrated and have an accuracy of $\pm 2\%$ of reading or better.

8.3.2 Adjustments to Baseline Demand

Before the new lighting fixtures are installed, adjustments to the baseline demand may be required for non-operating fixtures. In addition, after ECM installation, adjustments to baseline demand may be required because of remodeling or changes in occupancy. Methods for making adjustments should be specified in the site-specific M&V plan.

The party responsible for defining the baseline will also identify any non-operating fixtures. Non-operating fixtures are those that are *typically operating* and have broken lamps, ballasts, and/or switches that are *intended for repair*.

A de-lamped fixture is not a non-operating fixture. Thus, de-lamped fixtures should have their own unique wattage designations. Fixtures that have been disabled or de-lamped, or that are broken and not intended for repair, should not be included in the calculation of baseline demand or energy. They should, however, be noted in the lighting survey to avoid confusion.

For non-operating fixtures, the baseline demand may be adjusted by using values from the standard table of fixture wattages or from fixture wattage measurements. The adjustment for inoperative fixtures will be limited to some percentage of the total fixture count per facility; e.g., 10%. If, for example, more than 10% of the total number of fixtures are inoperative, the number of fixtures beyond 10% will be assumed to have a fixture wattage of zero.

8.3.3 Post-Installation Demand

For projects that involve only lighting controls, the post-installation demand is assumed to equal the baseline demand.

For projects with lighting efficiency and control measures, the measurement or definition of connected load will occur after all energy-efficiency retrofits have been installed to avoid double-counting the savings. For these projects, the post-installation conditions identified in the post-installation equipment survey will be defined by the ESCO and verified by the federal agency.

Savings for combined energy efficiency and lighting control projects are defined in the equation in Section 8.4.

8.3.4 Operating Hours

Baseline and post-installation operating hours will be stipulated and agreed to by the federal agency and the ESCO. Sources of stipulated hours can be any of the following:

- Building occupancy hours multiplied by a lighting load factor
- Premetering of representative areas by the ESCO or federal agency
- Results from other projects in similar facilities
- Studies of lighting operating hours.

Operating hours should be defined for each unique usage group within a building or facility that is being retrofit.

Usage groups are areas with similar operating hours (either annual operating hours, seasonal operating hours, or operating hours per the electric utility's time-of-use periods). Examples of usage groups are private offices, open offices, conference rooms, classrooms, and hallways. Within each group the range of operating hours should be narrow. Each usage group should have similar use patterns and comparable average operating hours.

8.4 Equations for Calculating Energy and Demand Savings

8.4.1 Energy

To avoid double counting lighting efficiency and control projects, the savings equation for combined projects is defined as follows:

$$\text{kWhSavings}_t = \sum_u [(kW/\text{Fixture} \times \text{Quantity} \times \text{Hours of Operation})_{\text{baseline}} - (kW/\text{Fixture} \times \text{Quantity} \times \text{Hours of Operation})_{\text{post}}]_{t, u}$$

where:

kWh Savings_t = the kilowatt-hour savings realized during the post-installation time period t

$\text{kW/Fixture}_{\text{baseline}}$ = the lighting baseline demand per fixture for usage group u

$\text{kW/Fixture}_{\text{post}}$ = the lighting demand per fixture during post-installation period for usage group u

$\text{Quantity}_{\text{baseline}}$ = the quantity of affected fixtures before the lighting retrofit adjusted for inoperative and non-operative lighting fixtures for usage group u

$\text{Quantity}_{\text{post}}$ = the quantity of affected fixtures after the lighting retrofit adjusted for inoperative and non-operative lighting fixtures for usage group u

$\text{Hours of Operation}_{\text{baseline}}$ = the total number of operating hours during the pre-installation period for usage group u

$\text{Hours of Operation}_{\text{post}}$ = the total number of operating hours during the post-installation period for usage group u .

The equation above is based on the two equations for lighting efficiency and lighting control projects that follow.

Savings for energy efficiency lighting projects are defined with the following equation:

$$\text{kWh Savings} = \sum_u [(kW/\text{Fixture} \times \text{Quantity})_{\text{baseline}} - (kW/\text{Fixture}^{\text{eff}} \times \text{Quantity})_{\text{post}}] \times \text{Hours of Operation}_{\text{post}}]_{t, u}$$

Savings for lighting control projects are defined with the following equation:

$$\text{kWh Savings}_t = \sum_u [(\text{Hours of Operation}_{\text{baseline}} - \text{Hours of Operation}_{\text{post}}) \times (kW/\text{Fixture} \times \text{Quantity}_{\text{baseline}})]_{t, u}$$

8.4.2 Demand

Demand savings can be calculated as either an average reduction in demand or as a maximum reduction in demand.

Average reduction in demand is generally easier to calculate. It is defined as kWh savings during the time period in question (e.g., utility summer peak period) divided by the hours in the time period.

Maximum demand reduction with respect to cost savings is typically the reduction in utility meter maximum demand under the terms and conditions specified by the servicing utility. For peak load reduction, for example, the maximum demand reduction may be defined as the maximum kW reduction averaged over 30-minute intervals during the utility's summer peak period. The maximum demand reduction is usually calculated to determine savings in utility peak demand charges. Thus, if utility demand savings are to be determined, each site must define (a) how the reduction will affect the utility bill and (b) how the demand reduction will be calculated for purposes of payments to ESCOs.

8.4.3 Interactive Effects

Lighting efficiency and controls projects may have the added advantage of saving more electricity by reducing loads associated with space-conditioning systems. The reduction in lighting load, however, may also increase space-heating requirements. Three options exist for estimating savings associated with the interactive effects of lighting efficiency projects:

1. Ignore interactive effects.
2. Use agreed-to, “default” interactive values such as a 5% addition to lighting kWh savings to account for additional air-conditioning savings.
3. Calculate interactive effects on a site-specific basis.

8.5 Pre- and Post-Installation Submittals

For each site, the ESCO submits a project pre-installation report that includes the following:

- A project description and schedule
- A pre-installation equipment survey
- Estimates of energy savings
- Documentation on utility billing data
- Projected budget
- Scheduled M&V activities.

If the federal agency defines the baseline condition, the ESCO must verify an agreed-to pre-installation equipment survey.

The ESCO submits a project post-installation report after the project is completed and defines projected energy savings for the first year. In addition, the report includes most of the components of the project pre-installation report, as well as information on *actual* rather than expected results of ECM installations.

8.6 Site-Specific Measurement and Verification Plan

The site-specific measurement and verification approach may be prespecified in the ESPC between the federal agency and the ESCO and/or agreed to after the award of the project. In either case, before the federal agency approves project construction, the ESCO must submit a final M&V plan that addresses the following elements on a site-specific basis:

- Overview of approach
- Specification of savings calculations
- Identification of corresponding variables and specification of assumptions
- Identification of data sources and/or collection techniques
- Specification of data collection (i.e., sampling, site inspection, and monitoring plan), if required
- Identification and resolution of any other M&V issues.

Specific M&V issues related to lighting efficiency and controls projects that must be addressed include the following:

- Decision whether to establish baseline fixture wattages at current efficiency standards

- Avoidance of double-counting the savings from energy-efficiency projects that are controlled
- Designation of usage groups for defining stipulated lighting operating hours
- Assessment of non-operating fixtures
- Choice of methods to account for changes to baseline and post-installation fixture counts and types due to remodels
- Identification of interactive impact approach.

In addition, project pre- and post-installation reports should identify the specific steps required to implement the M&V plan.

9

Constant-Speed Motor Efficiency: Metering of Motor kW

9.1 ECM Definition

Constant-speed motor efficiency projects involve the replacement of existing (baseline) motors with high-efficiency motors that serve constant-load systems. These ECMs are called constant-load motor efficiency projects because the power draw of the motors does not vary over time. These projects reduce demand and energy use.

This M&V method is appropriate only for projects where constant-load motors are replaced with similar capacity constant-speed motors, with two exceptions:

- Baseline motors may be replaced with smaller high-efficiency motors when the original motor was oversized for the load.
- Constant-speed motor drives may be adjusted to account for the difference in slip between the baseline motor and the high-efficiency motor.

If motor changes are accompanied by a change in operating schedule, a change in flow rate, or the installation of variable-speed drives, other M&V methods will be more appropriate.

9.2 Overview of Verification Method

Under Option A, Method CLM-A-01 is the only specified technique for verifying constant-load motor efficiency projects. This method assumes that the federal agency and the ESCO are confident that the motors operate at a consistent load with a definable operating schedule that can be stipulated.

Surveys are required to document existing (baseline) and new (post-installation) motors. The surveys should include (in a set format) the following data for each motor:

- Nameplate data
- Operating schedule
- Spot metering data

- Motor application
- Location.

Metering is required on at least a sample of motors to determine the average power draw for baseline and new motors. Demand savings are based on the average kW measured before new motors are installed minus the average kW measured after the new motors are installed. Allowances for differences in motor slip between existing and new motors may be allowed. Baseline and post-installation hours of operation, used in calculating energy savings, will be stipulated.

9.3 Calculation of Demand and Energy Savings

9.3.1 Baseline Demand

The baseline conditions identified in the pre-installation equipment survey will be defined by either the federal agency or the ESCO. If the baseline is defined by the federal agency, the ESCO will have an opportunity to verify the baseline. If the baseline is defined by the ESCO, the federal agency will verify the baseline.

Steps involved in establishing the baseline demand are as follows:

- Conduct a pre-installation equipment survey
- Spot metering of existing motors.

Pre-Installation Equipment Survey

In the pre-installation equipment survey, the equipment to be changed and the replacement equipment to be installed will be inventoried. Motor surveys with location information and corresponding building floor plans should be included with the survey submittal. The surveys will include, in a set format, nameplate data, motor horsepower, load served, operating schedule, spot metering data, motor application, and location.

Sample survey forms are included in Appendix B. Table M1 is the pre-installation survey form.

Spot Metering of Existing Motors

Instantaneous measurements of three-phase amps, volts, power factor (PF), kVA, kW, and motor speed in RPM should be recorded based on spot metering of each motor to be replaced. These data should be entered into a form such as the one shown in Table M2 (Appendix B). Such measurements should be made using a true RMS meter with an accuracy at or approaching $\pm 1\%$ of reading.¹ Other factors to measure include motor speed in RPM and the working fluid temperature if the motor serves a fan or pump. The temperature measurement may be taken at either the inlet or outlet of the device, as long as such location is identical for the baseline and post-installation measurements.

9.3.2 Adjustments to Baseline Demand

Before new motors are installed, adjustments to the baseline demand may be required for non-operating motors that are normally operating or intended for operation. In addition, after ECM installation, adjustments to baseline demand may be required owing to factors such as remodeling or changes in occupancy. Methods for making adjustments should be specified in the site-specific M&V plan.

With respect to non-operating equipment, the party responsible for defining the baseline will also identify any non-operating motors. Non-operating equipment is equipment that is *typically operating* but that has broken parts and is *intended for repair*.

9.3.3 Post-Installation Demand

The new equipment will be defined and surveyed by the ESCO and verified by the federal agency. The ESCO should enter the information in Table M1. After high-efficiency motors are installed, spot metering will be conducted for all motors using the same meter and procedures used for the baseline motors. The results are entered in Table M2. See Section 8.3.1.

9.3.4 Changes in Load Factor (Slip)

Standard-efficiency motors and high-efficiency motors may rotate at different rates when serving the same load. Such differences in rotational speed, characterized as “slip,” may lead to smaller savings than expected. Considerable impacts on savings due to slip may be reflected in the difference in load factor between the existing motor and a new high-efficiency motor. Large differences in load factor between the existing motor and the replacement high-efficiency motor may be symptomatic of other problems as well. As such, the ESCO will identify motors for which the difference in load factor between the high-efficiency motor and the baseline motor is greater than 10%. If the load factor is outside that range, the ESCO will provide an explanation, with supporting calculations and documentation. An acceptable reason for changes in load factor greater than 10% may be that the high-efficiency motor is smaller than the original baseline motor.

9.3.5 Operating Hours

Operating hours will be stipulated and agreed to by the federal agency and the ESCO. Sources of stipulated hours can be any of the following:

- Operation logs or documentation schedules from energy management systems
- Pre-metering of representative areas by the ESCO or federal agency

1. Report that, on the average, for all qualifying motors, the change in efficiency between a standard-efficiency motor and a high-efficiency motor, including an adjustment for slip, is 4.4%. As such, the resolution of meters used to measure instantaneous kW should be much smaller than 4.0%. Gordon et al. (Gordon, F.M. et al. “Impacts of Performance Factors on Savings From Motor Replacement and New Motor Programs.” ACEEE 1994 Summer Study on Energy Efficiency in Buildings. American Council for an Energy-Efficient Economy. 1994.)

- Results from other projects in similar facilities
- Studies of motor operating hours.

Operating hours can be estimated for each individual motor or for groups of motors with similar applications and schedules. Examples of such motor groupings are supply fan motors, exhaust fan motors, and boiler circulating pump motors. Each group type should have similar use patterns and comparable average operating hours. Baseline and post-installation operating hours may be different.

9.4 Equations for Calculating Energy and Demand Savings

Calculate the kWh savings using the following equations:

- If operating hours are the same before and after measure installation:

$$\text{kWh Savings (per each period)} = \text{Period Hours} \times \text{kW Savings}$$

$$\text{kWh Savings} = \text{kW}_{\text{baseline}} - \text{kW}_{\text{post}}$$

- If operating hours are different before and after measure installation:

$$\begin{aligned} \text{kWh Savings (per each pay period)} \\ = \text{Baseline Period Hours} \times \text{kW}_{\text{baseline}} - \text{Post-Installation Period Hours} \times \text{kW}_{\text{post}} \end{aligned}$$

where:

$\text{kW}_{\text{baseline}}$ = the kilowatt demand of the baseline motors

kW_{post} = the kilowatt demand of the high-efficiency motors

Period Hours = measured hours for a defined time segment, e.g., operating hours per year or hours per utility peak period.

These values may be corrected for changes in motor speed (slip) per section 9.3.4.

Demand savings may be calculated as:

- Maximum demand reduction:

$$\text{kW Savings}_{\text{max}} = (\text{kW}_{\text{baseline}} - \text{kW}_{\text{post}})_t$$

- Average demand reduction:

$$\text{kW Savings}_{\text{avg}} = \frac{\text{kWh Savings}}{\text{Period Hours}}$$

9.5 Pre- and Post-Installation Submittals

For each site, the ESCO submits a project pre-installation report that includes the following:

- A project description and schedule
- A pre-installation equipment survey
- Estimates of energy savings
- Documentation on utility billing data
- Projected budget
- Scheduled M&V activities.

If the federal agency defines the baseline condition, the ESCO must verify an agreed-to pre-installation equipment survey.

The ESCO submits a project post-installation report following project completion and defines projected energy savings for the first year. In addition, the report includes much of the same components as in the project pre-installation report, except that it contains information on *actual* rather than expected results from measure or ECM installations.

9.6 Site-Specific Measurement and Verification Plan

The site-specific measurement and verification approach may be prespecified in the ESPC contract between the federal agency and the ESCO and/or agreed to after the award of the project. In either case, before the federal agency approves the project construction, the ESCO must submit a final M&V plan that addresses the site-specific nature of the following elements:

- Overview of approach
- Specification of savings calculations
- Source of stipulated motor operating hours
- Specification of data collection methods, schedule, duration, equipment, and reporting format
- Identification and resolution of any other M&V issues.

Specific M&V issues that may need to be addressed and that are related to constant-load motor efficiency projects include the following:

- Operating hours for motors
- Assessment of non-operating motors
- Method(s) to account for changes in motor loading (slip) between baseline and new motors.

10

Variable-Speed Drive Motor Efficiency: Metering of Motor kW

10.1 ECM Definition

Variable-speed drive motor efficiency projects involve the replacement of constant-speed (baseline) motor controllers with variable-speed drive (or VSD) motor controllers. These projects reduce demand and energy use but do not necessarily reduce utility demand charges. Often VSD retrofits also include installation of new, high-efficiency motors. Typical VSD applications include HVAC fans and boiler and chiller circulating pumps.

This M&V method is appropriate only for VSD projects in which, for the baseline and post-installation motors, the following apply:

- Electrical demand varies as a function of operating scenarios—e.g., damper position for baseline or motor speed for post-installation; the electrical demand for each operating scenario can be defined with spot measurements of motor power draw.
- Operating hours as a function of operating scenario can be stipulated.

If the affected motor has a complex variable load profile and/or a complicated operating schedule, other M&V methods will be more appropriate.

10.2 Overview of Verification Method

Under Option A, method VSD-A-01 is the only specified technique for verifying VSD projects. This method assumes that the federal agency and the ESCO are confident that the affected motors operate with a definable operating schedule that can be stipulated.

Surveys are required to document existing (baseline) and new (post-installation) motors and motor controls (e.g., motor starters, inlet vane dampers, and VSDs). The surveys should include (in a set format) the following data for each motor and control device:

- Nameplate data
- Operating schedule

- Spot metering data
- Motor application
- Applicable end-use definitions
- Location.

Commissioning of VSD operation is expected.

Spot metering is required on at least a sample of the existing motors to determine baseline motor power draw under different operating scenarios. Constant-load motors may require only one spot measurement, since the power draw does not vary with time or operating scenario. Operating scenarios may include different control valve or damper positions (for baseline) or motor speeds (for VSDs).

Post-installation spot metering is required on at least a sample of motors with VSDs. Post-installation spot metering is done while the motors' applicable systems are modulated over their normal operating range (or range of motor speeds).

Demand and energy savings are based on the following:

- Baseline motor kW (calculated, if required, as a function of different operating scenarios)
- Post-installation motor kW (calculated as a function of different operating scenarios)
- Stipulated hours per year for each operating scenario.

10.3 Calculation of Demand and Energy Savings

10.3.1 Baseline Demand

The baseline conditions identified in the pre-installation equipment survey will be defined either by the federal agency or the ESCO. If the baseline is defined by the federal agency, the ESCO will have an opportunity to verify the baseline. If the baseline is defined by the ESCO, the federal agency will verify the baseline.

Steps involved in establishing the baseline demand are as follows:

- Conduct a pre-installation equipment survey.
- Spot metering of existing motors.

Pre-Installation Equipment Survey

In the pre-installation equipment survey, the equipment to be changed and the replacement equipment to be installed are inventoried. Motor location and corresponding facility floor plans should be included with the survey submittal. The surveys will include, in a set format, motor and motor control nameplate data, motor horsepower, load served, operating schedule, spot metering data, motor application, and location.

Spot Metering of Existing Motors

Instantaneous measurements of three-phase amps, volts, PF, kVA, kW, and motor speed in rpm should be recorded with spot metering for each motor to be replaced. These data should be entered into a standard form. Such measurements should be made using a true RMS meter with an accuracy at or approaching $\pm 2\%$ of reading. Other factors to measure include motor speed in rpm and the working fluid temperature if the motor serves a fan or pump. The temperature measurement may be taken at either the inlet or outlet of the device, as long as this location is identical for the baseline and post-installation measurements.

Multiple spot measurements are made while the affected systems are in each operating scenario in the normal operating range. For example, if there are inlet damper vanes affecting a fan motor, motor measurements are made while the dampers are in each possible position.

10.3.2 Adjustments to Baseline Demand

Before the new motors are installed, adjustments to the baseline demand may be required for non-operating motors that are normally operating or intended for operation. In addition, after ECM installation, adjustments to baseline demand may be required due to factors such as remodeling or changes in occupancy. Methods for making adjustments should be specified in the site-specific M&V plan.

With respect to non-operating equipment, the party responsible for defining the baseline will also identify any non-operating motors. Non-operating equipment is equipment that is *typically operating* but which has broken parts and is *intended for repair*.

10.3.3 Post-Installation Demand

The new equipment will be defined and surveyed by the ESCO and verified by the federal agency. After VSDs are installed, spot metering will be conducted for all motors using the same meter and procedures used for the baseline motors, and the results will be entered in a standard survey form. See part 10.3.1.

When the motor kW is recorded, the motor speed is also recorded. Direct motor rpm measurements can be made, or readings can be taken from the VSD control panel.

The power draw of the motors with VSDs will vary depending on the speed of the motor being controlled. In addition, other factors, such as downstream pressure controls, will affect the power draw. With this M&V method, the assumptions are as follows:

- Motor power draw can be defined with spot metering for specific operating scenarios.
- Operating hours can be assigned to each operating scenario.

Savings for VSD retrofits are defined within the equation presented in subsection 10.4.

10.3.4 Operating Hours

Operating hours will be stipulated and agreed to by the federal agency and the ESCO. Sources of stipulated hours can be any of the following:

- Operator logs or documented schedules from energy management systems
- Premetering of representative areas by the ESCO or federal agency
- Results from other projects in similar facilities
- Studies of motor operating hours (for example, using bin weather data).

Operating hours can be estimated for each individual motor or for groups of motors with similar applications and schedules. Examples of such motor groupings are supply fan motors, exhaust fan motors, and boiler circulating pump motors. Each group type should have similar use patterns and comparable average operating hours.

Operating hours will be defined for each operating scenario. For example, it may be assumed that a VSD operates at 25% speed or 3 kW for 2,500 hours per year and at 80% speed or 30 kW for 6,260 hours per year. See part 9.4 for a sample format of operating hour assumptions. Baseline and post-installation total operating hours may be different.

10.4 Equations for Calculating Energy and Demand Savings

Calculate the kWh savings using the following equations:

$$\begin{aligned} &\text{kWh Savings (per each operating scenario)} \\ &= \text{Operating Scenario Hours} \times \text{kW Savings per each operating scenario} \end{aligned}$$

where:

$$\text{kW Savings} = \text{kW}_{\text{baseline}} - \text{kW}_{\text{post}}$$

$\text{kW}_{\text{baseline}}$ = the kilowatt demand of the baseline motor in a particular operating scenario

kW_{post} = the kilowatt demand of the high-efficiency motor in a particular operating scenario

Operating Scenario = a particular mode of operation such as motor speed or valve position

Operating Hours = stipulated hours for each operating scenario.

Demand savings may be calculated as:

- Maximum demand reduction:

$$\text{kW Savings}_{\text{max}} = (\text{kW}_{\text{baseline}} - \text{kW}_{\text{post}}) \text{ per operating scenario}$$

- Average demand reduction:

$$\text{kW Savings}_{\text{avg}} = \frac{\text{Annual kWh Savings}}{\text{Annual Operating Hours}}$$

Table 10.1 contains examples of baseline and post-installation power draw measurements and savings calculations made using the equations above.

Table 10.1: Example of a Reporting Format

Scenario	Operating hours/year	Baseline kW measured	Percent VSD speed	Control valve position	Post-installation kW measured	kWh savings
1	1,000	30	50%	50%	15	15,000
2	3,000	35	50%	100% open	12	69,000
3	1,500	35	60%	100% open	20	22,500
4	2,000	35	70%	100% open	25	20,000
5	1,000	35	80%	100% open	30	5,000
Totals	8,500					131,500
Average kW Savings		15.5				
Maximum kW Savings		23				

10.5 Pre- and Post-Installation Submittals

For each site, the ESCO submits a project pre-installation report that includes the following:

- A project description and schedule
- A pre-installation equipment survey
- Estimates of energy savings
- Documentation on utility billing data
- Projected budget
- Scheduled M&V activities.

If the federal agency defines the baseline condition, the ESCO must verify an agreed-to pre-installation equipment survey.

The ESCO submits a project post-installation report following project completion and defines projected energy savings for the first year. In addition, the report includes most of the same components as the project pre-installation report, as well as information on *actual* rather than expected results from measure installations.

10.6 Site-Specific Measurement and Verification Plan

The site-specific measurement and verification approach may be prespecified in the ESPC between the federal agency and ESCO and/or agreed to after the award of the project. In either case, before the federal agency approves the project construction, the ESCO must submit a final M&V plan that addresses the following elements on a site-specific basis:

- Overview of approach
- Specification of savings calculations
- Source of stipulated motor operating hours
- Specification of data collection methods, schedule, duration, equipment, and reporting format
- Identification and resolution of any other M&V issues.

Specific M&V issues that may need to be addressed and that are related to VSD projects include the following:

- Definition of operating scenarios for motors
- Motor operating hours for each operating scenario
- Assessment of non-operating motors
- Meter specifications and spot metering methodology.

11

Chiller Replacement: No Metering and Verification of Chiller kW/ton Methods

11.1 ECM Definition

This ECM involves chillers used for space conditioning or process loads. Projects can include either of the following:

- Existing chillers replaced with more energy-efficient chillers
- Changes in chiller controls that improve chiller efficiency.

Two M&V methods are described in this chapter. For method CH-A-01, the chiller efficiency (e.g., kW per ton) and the chiller load (e.g., tons per year) are stipulated. For method CH-A-02, the chiller efficiency is measured and the chiller load is stipulated. Thus, these methods are appropriate *only for projects in which the baseline and post-installation chiller efficiency and/or the chiller load can be defined and stipulated by the ESCO and the federal agency.*

11.2 Overview of Verification Methods

Surveys are required to document existing (baseline) and new (post-installation) chillers and chiller auxiliaries (e.g., chilled water pumps and cooling towers). The surveys should include the following (in a set format) for each chiller and control device:

- Nameplate data
- Chiller application
- Operating schedules.

Commissioning of chiller operation is expected.

Method CH-A-01—No Metering

Baseline and post-installation chiller ratings (e.g., kW/ton or integrated part load value [IPLV]) are stipulated on the basis of manufacturers' or other data. Annual cooling loads (e.g., annual or monthly ton-hours) are also stipulated. Energy savings are based on the product of (a) the difference between average baseline kW/ton and post-installation kW/ton and (b) cooling load in ton-hours.

Method CH-A-02—Performance Measured

Baseline and post-installation chiller ratings (e.g., kW/ton, IPLV) are based on short-term metering of chiller kW (and perhaps auxiliary pump and cooling tower fan kW) and chiller load. Annual cooling loads (e.g., annual or monthly ton-hours) are stipulated. Energy savings are based on the product of (a) the difference between baseline kW/ton and post-installation kW/ton (possibly at each load rating) and (b) cooling load in ton-hours.

Methods CH-A-01 and CH-A-02 can be “mixed and matched” for the baseline chiller(s) and new chiller(s). For example, baseline chiller efficiency may be measured, and manufacturer's data can be used to stipulate performance ratings for the new chiller.

Baseline and post-installation chiller load can be different to account for changes in load during the term of the contract.

11.3 Calculation of Demand and Energy Savings

11.3.1 Baseline Demand

The baseline conditions identified in the pre-installation equipment survey will be defined by either the federal agency or the ESCO. If the baseline is defined by the federal agency, the ESCO will have the opportunity to verify the baseline. If the baseline is defined by the ESCO, the federal agency will verify the baseline.

Steps involved in establishing the baseline demand are:

- Pre-installation equipment survey
- Defining chiller efficiency (method CH-A-01) or metering existing chillers (method CH-A-02).

Pre-Installation Equipment Survey

In the pre-installation equipment survey, the equipment to be changed and the equipment to be installed will be inventoried. Chiller location and corresponding facility floor plans should be included with the survey submittal. The surveys will include, in a set format:

- Chiller and chiller auxiliaries nameplate data
- Chiller age, condition, and ratings
- Load served
- Operating schedule
- Chiller application
- Equipment locations.

Method CH-A-01—Stipulated Chiller Efficiencies

For this simple M&V method, the chiller performance is stipulated—i.e., agreed to by the federal agency and the ESCO. The most common source of chiller performance data is the manufacturer. For existing chillers, the “nameplate” performance ratings may be downgraded based on the chillers’ age and/or condition (e.g., fouling). Chiller efficiency can be presented in several formats, depending on the type of load data that will be stipulated. Possible options include annual average kW/ton, expressed as the IPLV or kW/ton per incremental cooling loads for the chiller(s) affected by the ECM.¹

Method CH-A-02—Metering of Existing Chillers

For this M&V method, the baseline chiller efficiency is measured. The following data should be collected:

- Chiller kW
- Chilled water flow, entering and leaving temperatures for calculating cooling load
- Chiller circulating and condenser pumps kW (kWh) if they are to be replaced or modified
- Cooling tower fan(s) kW (kWh) if they are to be replaced or modified.²

These data should be entered into a standard form. Such measurements should be made using a meter with an accuracy at or approaching $\pm 2\%$ of reading.

Multiple measurements are made while the cooling systems are operating at different loads so that the complete range of chiller performance can be evaluated. Optimally, baseline metering is performed during a period where a range of cooling loads exist (e.g., summer).

ASHRAE is preparing chiller measurement protocols (e.g., RP-827) that may be specified by the federal agency.

11.3.2 Post-Installation Demand

The new equipment will be defined and surveyed by the ESCO and verified by the federal agency.

1. For example, per the appropriate standards of the Air-Conditioning and Refrigeration Institute

2. Condenser pumps and cooling tower measurements are not involved in air-cooled systems. Circulating pump measurements are not involved in DX systems. Condenser flows and temperatures can also be measured to check system energy balances. For DX systems, air flows and temperatures (although more difficult than water system measurements) are measured to determine cooling load.

11.3.3 Cooling Load

Cooling load will be stipulated—that is, agreed to by the federal agency and the ESCO. Sources of stipulated data can be any of the following:

- Calculations of cooling load (for example, using bin weather data or computer simulation programs such as DOE-2)
- Pre-installation metering of cooling loads by the ESCO or federal agency
- Results from other projects in similar facilities.

Baseline and post-installation cooling loads may be different.

11.4 Equations for Calculating Energy and Demand Savings

Calculate the kWh savings using the following equations:

$$\begin{aligned} \text{kWh Savings} \\ &= (\text{Cooling Load in Ton-Hours}) \times (\text{Baseline kW/ton} - \text{Post-installation kW/ton}) \end{aligned}$$

where:

Cooling Load in Ton-Hours is stipulated and can be different for baseline and post-installation

Baseline kW/ton = the stipulated or measured existing chiller performance

Post-installation kW/ton = the stipulated or measured new chiller performance.

Demand savings may be calculated as:

- Maximum demand reduction:

$$\text{kW Savings}_{\text{max}} = (\text{kW}_{\text{baseline}} - \text{kW}_{\text{post}}) \text{ per cooling load}$$

- Average demand reduction:

$$\text{kW Savings}_{\text{avg}} = \frac{\text{Annual kWh Savings}}{\text{Annual Operating Hours}}$$

Table 11.1 contains a summary of example baseline and post-installation power draw measurements and savings calculations (using the above equations).

Table 11.1: Example Reporting Format

Scenario	Operating hours/year	Stipulated cooling load (tons)	Baseline chiller (kW/ton)	Post-installation chiller (kW/ton)	kWh Savings
1	1,000	400	1.0	0.7	120,000
2	3,000	350	1.1	0.8	315,000
3	1,500	300	1.2	0.9	135,000
4	2,000	200	1.3	1.0	120,000
5	1,260	0	n/a		0
Totals	8,760				690,000
Average kW Savings			79 kW		
Maximum kW Savings			120 kW		

11.5 Pre- and Post-Installation Submittals

For each site, the ESCO submits a project pre-installation report that includes the following:

- A project description and schedule
- A pre-installation equipment survey
- Estimates of energy savings
- Documentation on utility billing data
- Projected budget
- Scheduled M&V activities.

If the federal agency defines the baseline condition, the ESCO must verify an agreed-to pre-installation equipment survey.

The ESCO submits a project post-installation report following project completion and defines projected energy savings for the first year. The report includes most of the components of the project pre-installation report, as well as information on *actual* rather than expected ELM installations.

11.6 Site-Specific Measurement and Verification Plan

The site-specific measurement and verification approach may be prespecified in the ESPC between the federal agency and the ESCO and/or agreed to after the award of the project. In either case, before the federal agency approves the project construction, the ESCO must submit a final M&V plan that addresses the following elements on a site-specific basis:

- Overview of approach
- Specification of savings calculations
- Source of stipulated chiller performance and/or cooling loads
- Specification of data collection methods, schedule, duration, equipment, and reporting format
- Identification and resolution of any other M&V issues.

Specific M&V issues that must be addressed and that are related to chiller replacement projects include the following:

- Definition of operating scenarios
- Cooling loads of the chillers at each operating mode
- Duration of monitoring.